Investigating Bobcat-Recreation Conflict in Vermont

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Table of Contents

Executive Summary 3

Introduction 4

  Importance of Recreation 4

  Background on Overall Impact of Recreation on Wildlife 5

Focal Species: Bobcats 6

  Bobcat Habitat 6

  Impact of Recreation on Bobcats 7

Pilot Study 8

  Camera Trapping Methods 8

    Camera Parameters 8

    Timing and Duration 9

    Camera Placement 9

    Image Processing and Data Analysis 10

  Study Site Selection 10

Habitat Modeling 11

Conclusion 14

Acknowledgements 14

Bibliography 15

Appendix 1: Habitat Suitability Model Procedure 18

Executive Summary

The Northeast Wilderness Trust (NEWT) is a land trust that is wholly dedicated to the conservation of wilderness areas in the northeastern United States, including New England and the Adirondacks. Founded in 2002, NEWT seeks to conserve “forever wild landscapes for nature and people.” As wild lands in the northeast rebound from deforestation in the 19th century, NEWT emphasizes that the need to provide sanctuary for the continued recovery of these landscapes has never been greater. In pursuit of this end, NEWT is primarily concerned with preserving the “wilderness” of lands “where ecological processes unfold without human interference and...that are free of roads and motorized recreation, extractive practices such as logging and farming, and human development” (*About*).

While the conservation of nature for its intrinsic and ecological value is NEWT’s ultimate mission, the Trust recognizes that human use of nature for recreation and science is also vital to understanding and protecting wild lands. Land managed by NEWT falls onto a spectrum of allowed recreation: some lands are privately owned with no public access, some have public access with no trail infrastructure, and others have trail infrastructure. Where public access is allowed, NEWT permits quiet, muscle-powered recreation and limited hunting upon permission (*Places We Protect*). Recreation restrictions and preservation priority are determined based on the wilderness potential of, community vision for, and threat abatement associated with the ecosystem in question. The Trust strives to understand how recreation type and trail density impact wildlife in the wilderness areas they own and protect. NEWT believes that articulating the impacts of recreation on wildlife will support their stance on the value of wild lands and help convince landowners of the importance of protecting wilderness areas with limited to no recreation.

To support this goal in our partnership with NEWT, we compiled a comprehensive literature review into wildlife-recreation conflict, with a focus on bobcats (*Lynx rufus*), developed a pilot study to investigate the impacts of multi-use trail networks on bobcats in Vermont, and created a habitat suitability index and model to identify and compare study sites. With these tools, we sought to address three overarching questions: (1) how can extant studies into wildlife-recreation conflict in other regions inform research in Vermont, (2) what are the best methods for a pilot study focused on the impact of complex multi-use trail networks on bobcats in Vermont, (3) what additional resources and materials are useful to our partner in continuing to develop this investigation?

Ideally, a range of several organisms of focus, across several ecological niches and trophic levels, would create a more complete picture, but to save time and resources, we have chosen a focal species as a bioindicator. Bobcats proved of interest to NEWT and an effective focus species for several reasons. Bobcats are present throughout Vermont and have been studied in the Middlebury area (Donovan et al., 2011; Farrell et al., 2018), and they are umbrella species whose protection ensures the protection of a suite of other species (Roberts et al., 2010). Additionally, bobcats are a charismatic fauna that will prove effective in garnering public support for its protection. There is currently little research on the impacts of recreation on wildlife in New England, and it is our hope that the literature review, pilot study, and habitat suitability model we generate prove useful in expanding this knowledge base.

Our pilot study provided a detailed framework for NEWT and future collaborating groups to conduct research into whether the presence of multi-use trail networks impact local bobcat populations. We have identified four multi-use trail networks within the greater Champlain

Valley area that could serve as eligible study sites: Chipman Hill, Battell Woods, and Wright Park on the Trail around Middlebury (TAM) in Middlebury; Green Mountain Trails in Pittsfield; Hinesburg Town Forest and Carse Hill in Hinesburg; and the Catamount Outdoor Family Center in Williston. Using GIS, we characterized the ecology, physical environment, and anthropogenic influence present in these study sites and assessed their suitability for supporting bobcats. Then, we generated a habitat suitability model to identify areas without trails that exhibit the same environmental characteristics as our trailed study locations to act as control sites. Additionally, we provide NEWT with the processed data and workflow to replicate this model for other focal species. We hope that our study design and habitat model will prove useful tools for NEWT to study the impacts of recreation on wildlife and promote their mission to protect wilderness areas, as well as expand regional understanding of wildlife-recreation conflict in the northeast.

Introduction

Importance of Recreation

Understanding the importance of recreation and wildlife interactions, including weighing the positives and negatives of trail networks, requires an appreciation of the importance of outdoor recreation for humans. Contact with nature benefits human health by encouraging physical activity, promoting social cohesion, and reducing stress (Hartig et al., 2014). Physical activity in open spaces and woodlands is associated with a reduced risk for poor mental health, while physical activity in indoor or highly-developed spaces is not (Mitchell, 2013). These positive health effects do not go unnoticed, and many global citizens take advantage of protected natural areas for outdoor recreation. Globally, there are approximately 8 billion visits to protected natural areas per year, with approximately $600 billion in gross expenditures associated with these visits (Balmford et al., 2015). In North America, each protected area receives, on average, 350,000 visits per year (Balmford et al., 2015).

However, the paradox of outdoor recreation is that while many people see accessibility to outdoor recreation as a conservation tool, since it can teach people about nature and drive the protection of natural areas, it can also have negative consequences for wildlife. Our goal is to come up with a balance between allowing people to appreciate and experience nature and protecting it for its own value. It is important for all recreators to think about the paradox of recreation: by recreating outdoors, we gain a larger appreciation for and a larger urge to protect nature, but we may also be actively harming it. Protected areas must therefore find a balance between providing protection for wildlife and recreation opportunities for people (Kays et al., 2017). Our hope was to, alongside Northeast Wilderness Trust, contribute a research methodology that helps identify how this balance between allowing recreation while simultaneously protecting nature might be achieved.

Background on Overall Impact of Recreation on Wildlife

While many knowledge gaps remain, there is general consensus that recreation can have a negative impact on nearby wildlife, and there is evidence that non-motorized recreation can even have more negative effects than motorized recreation (Larson et al., 2016). Even when recreators do not perceive their impacts on wildlife, their sounds and other disturbances can be magnified to the animals around them. A survey of recreationists in Utah found that over 50% recreationists felt that recreation did not have an impact on local wildlife, an indication that the perceived effect of recreation is much smaller than the actual one (Taylor & Knight, 2003). Mitigating recreation-wildlife conflicts will require educating recreators on their negative impacts.

The negative consequences of recreation for wildlife stems from a fear of humans as "super predators," with the result being that many species shift their behavior spatially or temporally to avoid contact with humans (Suraci et al., 2019). Simply playing a recording of human conversation was found to change the spatial and temporal behavior of mountain lions, bobcats, skunks, opossums, and small mammals, with landscape-level consequences (Figure 1; Suraci et al., 2019). Predation risk theory explains that animal responses to human presence are likely to follow the same economic principles used by prey encountering predators (Frid & Dill, 2002). In order to avoid these "super predators," animals will make energy expenditures, like fleeing, increasing vigilance, shifting activity patterns, or avoiding fitness-increasing activities such as mating or hunting.

Figure 1. An illustration of the landscape-scale impacts of recreators on wildlife. Human activity causes fear responses in large carnivores and mesocarnivores that enable greater foraging by small mammals. Based on a study in CA by Suraci et al. (2019).

There are steps that conservationists can take to minimize recreation-related impacts on wildlife. Generally, impacts can be reduced by placing trails outside of sensitive and high-quality wildlife habitat and by closing trails seasonally (Marion & Wimpey, 2007). Of course, this requires an understanding of the focal species' niche. When protecting wildlife, it is important to consider habitat resources for the species of interest: prey base, mates, refugia, denning and rearing sites for young (Donovan et al., 2011). Working with the animal's ecology to make sure that its habitat is being protected efficiently is the best way to ensure that the impacts of recreation are kept to a minimum.

Finally, while it is important to recognize and limit the threat of recreation to wildlife, it is more important to ensure land is protected and habitat remains undeveloped. There are strong connections between increasing human density and increasing carnivore extinctions (Woodroffe, 2000). While recreation is a threat to wildlife, it is important to note that landscape-level changes such as forest fragmentation and housing density have a greater impact on wildlife than recreation (Kays et al., 2017). It is vital to prioritize connectivity of forest as well as specific landforms and vegetation types that support the focal species.

Focal Species: Bobcats

For this project, we chose to use the bobcat as our focal species. Ideally, a study examining the effects of recreation on wildlife would examine a set of species across different ecological niches, but such a study would require time and resources that NEWT and other collaborating groups likely would not have. While bobcats are not a species of conservation concern, there are a number of other reasons bobcats are an ideal focal species for a pilot study (Kelly et al., 2016). Bobcats are pervasive throughout Vermont, meaning that we can find a number of study sites and control sites that support bobcat populations that are large enough to study (Donovan et al., 2011; Farrell et al., 2018). Bobcats are frequently a focal species for wildlife studies, meaning that there is a plethora of methods available for studying bobcats that we can adapt to suit the needs of study sites in Vermont (e.g. George & Crooks, 2006; Nickel et al., 2020). Furthermore, bobcats are an umbrella species; protecting ideal bobcat habitat involves protecting large swaths of undisturbed land, which in turn protects habitat for a host of other animals (Roberts et al., 2010). For these reasons, we felt that bobcats were an ideal species to focus on for a pilot study and that methods and models developed for studying bobcats could be adapted to study other mesocarnivores.

<u>Bobcat Habitat</u>

Bobcats are habitat generalists and can be found across the continental United States in a variety of plant communities, including coniferous forest, deciduous forest, mixed forest, the Everglades, prairie and other grasslands, chaparral, sagebrush (*Artemisia spp*.), scrubland, creosote bush (*Larrea tridentata*) scrubland, and mesquite (*Prosopis spp.*) scrubland (Tesky, 1995).

In Vermont, bobcats use a wide range of habitats, but they prefer covered areas for concealment and protection from exposure and uneven terrain (Sunquist & Sunquist, 2017). They are most commonly found in northern white cedar swamps and black spruce thickets, though they are also found in mixed hardwood forests (Sunquist & Sunquist, 2017; Tesky, 1995). The winter season impacts bobcat habitat selection; they tend to avoid areas with a snow

depth greater than 15 cm to reduce the energy they have to expend to move around (McCord, 1974; Sunquist & Sunquist, 2017). They prefer areas with ledges and rocky outcrops, which offer protection and serve as good denning sites (McCord, 1974; Sunquist & Sunquist, 2017; Tesky, 1995). Bobcats prefer to hunt in shrub and scrub areas including clear cuts, young pine plantations, and farms, and their diet includes mice, porcupines, cottontail rabbits, squirrels, snowshoe hares, and deer (Pollack, 1951; Tesky, 1995).

Habitat fragmentation is of particular concern for bobcats, as they generally have a low population density and large home ranges (Donovan et al., 2011). They are much less likely to be found in small, isolated habitat fragments than in larger, connected swaths of habitat (Preuss & Gehring, 2007). Habitat connectivity is especially important for bobcats, as a decrease in genetic diversity since the 1950s was linked to a decrease in habitat connectivity (Carroll et al., 2019). In Iowa, disappearance of bobcats was associated with deforestation and fragmentation, highlighting the importance of protected lands in maintaining bobcat populations (Tucker et al., 2008). For these reasons, bobcats are a prime example of the recreation-wilderness paradox: their survival relies on the protection of large swaths of habitat, but these swaths are also important areas for recreation. If NEWT is looking to protect areas where wildlife such as bobcats can thrive, they must determine whether or not recreation in these protected areas will allow wildlife to thrive. It is thus important to understand the extent to which recreation impacts bobcats in protected areas.

<u>Impact of Recreation on Bobcats</u>

The impacts of recreation on bobcats have been studied in the west and southwest (CA, AZ), outside of metropolitan New York City, and along the Appalachian Trail Corridor. We did not find any studies looking at the impacts of recreation on bobcats in New England. New England hosts different ecosystems than those in which the impacts of recreation on bobcats were previously studied. We feel it is important to conduct a study in New England before drawing conclusions about the impact of recreation, as different ecosystems may promote different behaviors that impact how bobcats react to recreation.

Bobcats generally seek to avoid humans, either through temporal or spatial avoidance. To avoid humans temporally, bobcats become more active at night, when humans are less active. As human presence and trail use increases, bobcat nocturnality increases (George & Crooks, 2006; Nickel et al., 2020; Stark et al., 2020). Recordings of human conversation were found to decrease the diurnal activity of bobcats by 31% (Suraci et al., 2019).

To avoid humans spatially, bobcats tend to move out of areas of high human activity (George & Crooks, 2006). However, in areas where an increase in human presence overlaps with high-quality bobcat habitat, bobcats may remain in the area, as spatial avoidance would be costly (Nickel et al., 2020). A study in AZ found that bobcat occupancy was negatively correlated with trail use, indicating bobcats avoid trails that are heavily used by humans (Baker & Leberg, 2018)**.** Areas with quiet, non-consumptive recreation in CA (i.e. hiking, biking, and horseback riding—similar to the recreation that NEWT permits) had a five-times lower bobcat density than areas without (Reed & Merenlender, 2008). Hunting, which is allowed with permission on NEWT lands, on lands adjacent to the Appalachian Trail corridor has been found to reduce bobcat occupancy along the Appalachian Trail corridor (Erb et al., 2012). A study on the impacts of recreation on bobcats in Vermont should focus on determining if recreation alters the temporal or spatial activity of bobcats.

Pilot Study

We extended our literature review to develop a pilot study into the impacts of recreation on bobcats in Vermont in keeping with Northeast Wilderness Trust's interest in the impact of trail density on wildlife in the region. As noted, relatively little research exists on the impacts of recreation on bobcats in New England. This case study will be an integral stepping stone toward a larger understanding of wildlife-recreation dynamics in Vermont. Additionally, better understanding of these dynamics will inform NEWT's approach to promoting and protecting wilderness land in the region. We reviewed studies of bobcat-recreation conflict on a range of spatial scales and in diverse locations in order to identify the methods most appropriate for studying this phenomenon in Vermont. By using the abundance of similar studies that have been conducted in other regions as a resource, we were able to extract methods to synthesize an informed pilot study specifically attuned to bobcat-recreation conflict in Vermont.

The goals of this study are unique from many of those included in our literature review because the purpose of this study is not to determine absolute abundance or population size. ***This study aims instead to provide a relative comparison in bobcat populations between areas with and without complex trail networks on land that is otherwise environmentally comparable.*** Therefore, many of the more complex modeling strategies and comprehensive tracking methods used in estimating population size are not necessary in this pilot study.

Camera Trapping Methods

There has been a noteworthy increase in the use of camera traps in wildlife monitoring and research over the past few decades (Rovero et al., 2013). We determined that camera trapping would be the most appropriate method for our and our partner's purposes for a number of reasons: (1) camera traps collect high quality data that can be corroborated out of the field by experts, (2) camera trapping studies maximize field sampling capacity and efficiency for small research teams, and (3) camera trapping minimizes impact on surrounding ecology, which is a factor that is especially relevant in our wilderness control sites and of interest to NEWT. Other methods such as telemetry, genetic sampling, and the use of detector dogs proved effective, but were too expensive, and we concluded that scat surveys, sand trapping, hair snares, and scent stations were too nuanced and resource intensive for the purpose of our study (Bateman & Fleming, 2017; Harrison, 2010).

Camera Parameters

The vast majority of studies that employed camera trapping as a method used remotely triggered infrared cameras (Baker & Leberg, 2018; Erb et al., 2012; George & Crooks, 2006; Jacques et al., 2019; Rovero et al., 2013; Stark et al., 2020). Some studies supplemented camera trapping with other methods like track plates, though most used camera trapping alone (Baker & Leberg, 2018). As this study is not concerned with estimating population size, it can be considered a faunal detection study, which is a type of study concerned with achieving as many detection events as possible (Rovero et al., 2013).

Fast shutter speed, wide detection zone, and high sensitivity are parameters that are especially important to faunal detection studies. A camera with a fast shutter speed increases the likelihood that the camera will capture the animal that triggered it, though a large detection zone

or strategically placed attractants may compensate for a slower shutter speed (Rovero et al., 2013). White flash cameras produce colored photography and are more likely to be used in studies that depend on the identification and recapture of individuals (Rovero et al., 2013). Though infrared flash cameras produce monochrome images, they are energy efficient, less stressful to wildlife than white flash cameras, and more broadly used (George & Crooks, 2016; Rovero et al., 2013). All cameras should be set for continuous action in order to ensure that all instances of bobcats within the detection zone are recorded (Baker and Leberg, 2018; George & Crooks, 2006). Examples of remotely triggered infrared cameras used in other studies include the Browning Recon Force (Model BTC-7FHD), Cuddeback Digital, Moultrie M-880i, and Bushnell Trophy Cameras (Baker & Leberg, 2018; Erb et al., 2012; Jacques et al., 2019; Nickel et al., 2020).

Timing and Duration

We propose that the pilot study should be conducted in the transition from winter to spring in order to reduce risk of camera vandalism and obstruction from foliage (Jacques et al., 2019). Additionally, bobcat habitat range is restricted in winter in favor of denser conifer stands, making target study sites more easily identifiable (Lovallo & Anderson, 1996; McCord, 1974; Tesky, 1995). However, it is worth considering recreational trail use is often more limited in winter months, so the impacts of recreation may be less visible between wild control sites and trailed treatment sites (Larson et al., 2016). Early spring also coincides with bobcat breeding season, during which activity and mobility is increased and occurrence is more predictably proximate to rocky ledge and denning sites (Donovan et al., 2011; Jacques et al., 2019; McCord, 1974).

Bobcat camera trapping studies can range in duration from 30 days (Erb et al., 2012; Kays et al., 2020; Rovero et al., 2013) to multiple months (Jacques et al., 2019; Stark et al., 2020), to more than 4,000 days (George & Crooks, 2006). Some studies use distinct sampling periods that coincide with seasons in order to observe changes in bobcats' response to recreation as recreation intensity and type shifts with the seasons (Baker & Leberg, 2018; Nickel et al., 2020). In faunal detection studies, cameras should be left at the study site for at least 30 days (Rovero et al., 2013), though camera deployments of shorter durations such as this are often repeated over longer periods of time for best and most comprehensive results (Erb et al., 2012).

Camera Placement

Cameras should be placed approximately 0.3 meters or knee level above ground level on either a stake or stable vegetation (Baker & Leberg, 2018; Erb et al., 2012; Jacques et al., 2019; Nickel et al., 2020). When possible, cameras should be placed facing north to prevent images from being washed out by the sun (C. Wood, personal communication, March 6, 2020). As some studies report vandalism and theft of some cameras, thought should be given to obscuring their placement, especially along trails, without blocking the lens with brush or foliage (George & Crooks, 2006). Many faunal detection studies use attractants ranging from cat food to reflective CDs to increase the likelihood of capture (Baker & Leberg, 2018; Erb et al., 2012; Rovero et al., 2013; Jacques et al., 2019). Baiting cameras increases "occupancy probability," or the probability that each camera site is occupied by the target species, which in turn increases

detection rates and reduces the number of cameras necessary to produce an extensive data set (Kays et al., 2020).

Some studies arrange cameras along and oriented toward trails (George & Crooks, 2006; Nickel et al., 2020), though some use random point generators within study sites or between survey units of equal area to select camera locations (Baker & Leberg, 2018; Jacques et al., 2019; Stark et al., 2020). Cameras are often placed facing one another approximately 2 meters perpendicular to the trail and offset by 5 meters with the goal of producing bilateral images (Jacques et al., 2019; Rovero et al., 2013). Most studies report a minimum distance of 1 km between camera stations, and this paired camera arrangement can be used in studies with randomly selected and trail-oriented cameras (Baker & Leberg, 2018; Erb et al., 2012; Nickel et al., 2020; Stark et al., 2020). For study areas smaller than 1 km^2, 20 cameras are necessary for a comprehensive detection study (Kays et al., 2020). For areas of more than 1000 km^2, the number of cameras used in faunal detection studies can range from 49 to 88 cameras (Jacques et al., 2019; Kays et al., 2020; Nickel et al., 2020).

Image Processing and Data Analysis

Some studies consider images of the same species taken within a certain period to be independent captures (Nickel et al., 2020; Stark et al., 2020), while others require that a photograph at one or more camera stations must occur within an hour to be considered a capture event (Jacques et al., 2019). The requirements for an image to be considered a capture event largely depend on how far apart the camera stations are placed and what type of questions the study is interested in investigating.

For a study that does not aim to estimate population size, an index of relative activity such as that used by George and Crooks (2006) can be used to draw comparisons between two sites. George and Crooks define the index of relative activity as the number of images of the target species divided by the number of nights the camera was active. Stark et al. (2020) use this same index but refer to it as an index of relative abundance. These indices allow for a comparison of spatial displacement as a result of recreation activity in sites where multi-use trail networks are present. Considering the relationship between percent daytime and nighttime activity allows for temporal displacement of bobcats are a result of recreational activity to be assessed (George & Crooks, 2006).

<u>Study Site Selection</u>

This pilot study is concerned with a relative comparison of bobcat abundance between land characterized by trail networks and land that is wild and of priority for protection to our partner. We selected the five most popular and largest multi-use trail networks in central Vermont based on their proximity to Middlebury, Vermont to serve as treatment sites: the TAM (specifically the Chipman Hill, Battell Woods, and Wright Park trail networks) in Middlebury; the Green Mountain Trails in Pittsfield; the Catamount Family Outdoors Center in Williston; and the Hinesburg Town Forest and adjacent Carse Hill in Hinesburg (Figure 2). Sites were initially selected based on proximity to Middlebury with the assumption that initial trials would be conducted at the end of the semester.

As there is great variation in the ecology and physical environment of any two given sites, paired control sites were identified using a geospatial habitat model in GIS. This method

takes steps toward isolating the presence of trail networks as the only factor under investigation by controlling for other ambient environmental factors that might influence differences in bobcat populations between sites. The habitat model described in detail in the following section was developed for this purpose, as well as to quantify and rank overall suitability between paired sites.

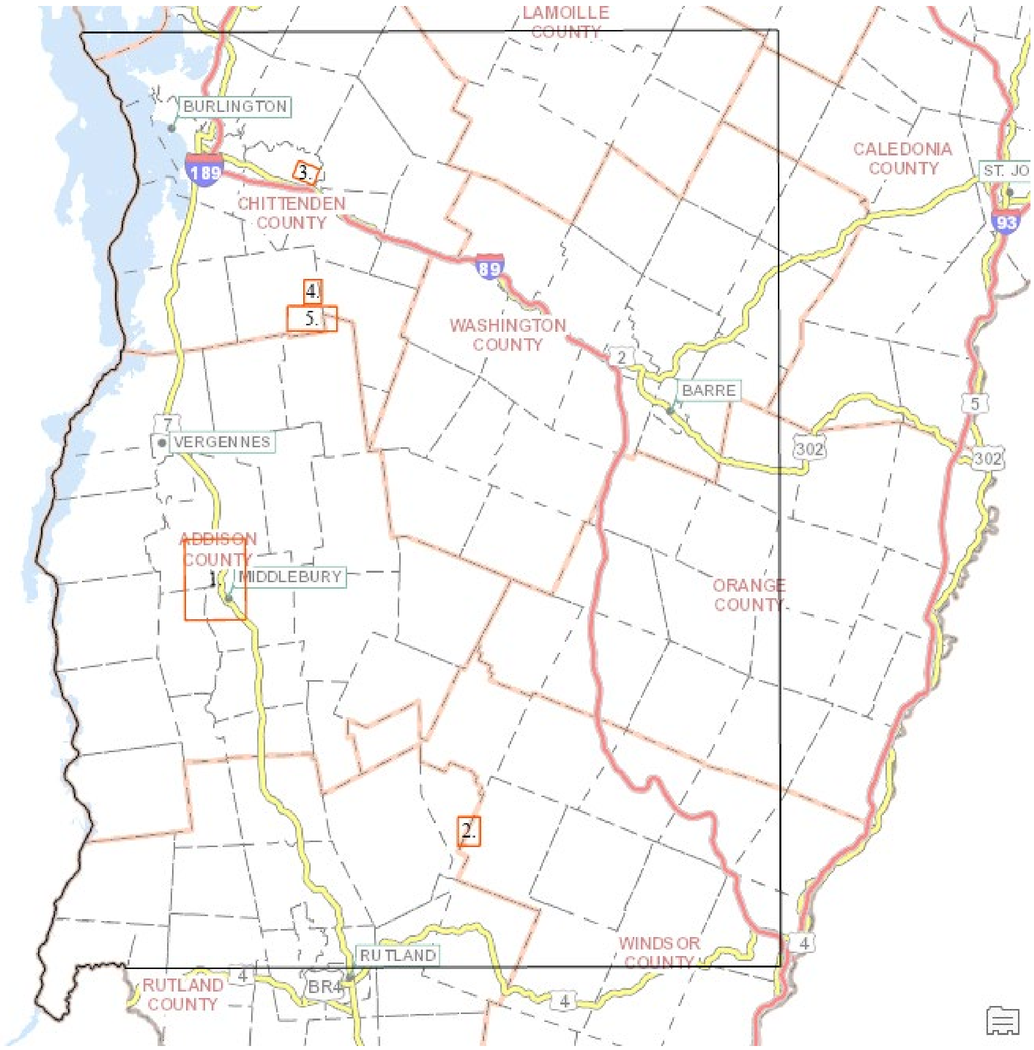

Figure 2. Five potential multi-use trail network study sites outlined in red. 1 corresponds to the TAM, 2 to Green Mountain Trails, 3 to Catamount Family Outdoors Center, 4 to Hinesburg Town Forest, and 5 to Carse Hill.

Habitat Modeling

The goals of the bobcat suitability habitat model are as follows: (1) ensure paired study sites exhibit comparable underlying ecology and bobcat suitability, (2) characterize ideal bobcat habitat and compare habitat suitability amongst paired sites, and (3) serve as a resource to NEWT in carrying out this pilot study using these or other study sites. Literature on bobcat ecology and other bobcat habitat and movement models support the habitat parameters used in

this study, and the calculations used to generate the habitat suitability index (HSI) are adapted from a study by Roberts et al. (2010) that uses a spatial habitat suitability model and index to prioritize conservation efforts. Few models for bobcat habitat suitability in Vermont exist, so this study draws on what is known of bobcat ecology and habitat preference in New England and adapts existing models to reflect these region-specific preferences. Evaluating and selecting study sites using this model also ensures that resources are being used efficiently by increasing capture probability (Ruell et al., 2009).

This model prioritizes habitat blocks and connectivity in describing habitat suitability with secondarily consideration to forest cover type and proximity to denning sites, wetlands, and riparian corridors (Linde, 2010; Roberts et al., 2010; Tucker et al., 2008). The forest block index (FBI) is based on a score generated through a weighted average of 11 biological and physical diversity ranks developed by the Vermont Agency of Natural Resources (Vermont Agency of Natural Resources, 2019). Only lands greater than 20 acres are considered in this model and those that are fragmented or within small forest blocks are ranked lower, which reflects bobcats' sensitivity to fragmentation (Farrell et al., 2018; Tucker et al., 2008). These forest blocks serve as the foundation for the model, and lands that do not qualify to be included are excluded entirely, regardless of forest cover type and proximity to denning sites, wetlands, and riparian corridors.

Landcover appropriateness within these blocks is characterized using the land cover index (CSI), which ranks coniferous forests as optimal bobcat winter habitat and hunting ground, followed by deciduous forest, and then shrublands (e.g. lands characterized as coniferous forests are ascribed a CSI of 3, while deciduous forests are ascribed a 2 and shrublands a 1). Additionally, land with forest and shrub cover within prescribed distances from roads and residence are excluded from this model (CSI = 0). Rocky outcrops and ledges are important to bobcat denning, and as mating season coincides with the time during which this study is recommended to take place, land within a 2 hectares area of cliffs are prioritized (DSI = 1). As riparian corridors and wetlands provide an important water resource and serve as an indicator of ecosystem diversity, the water availability index (WAI) prioritizes wetlands and land within 150 meters from rivers and streams (WAI = 1). After preparing the spatial data according to Appendix 1, each component index (FBI, CSI, DSI, WAI) was rasterized and reclassified to reflect its respective index value. A habitat suitability index value for each location (Table 1) within the raster was then calculated using an equation adapted from Roberts et al. (2010):

$$HSI = FBI \times [(CSI + DSI + WAI)/5].$$

These findings and habitat suitability index scores for the five study sites in central Vermont provide a useful foundation for considering paired control sites for each (Figure 3). Additionally, scoring the paired sites in this way provides insight into why one set of paired sites may support a larger bobcat population than another set. Though basic, this model provides a foundation for assessing and studying bobcat habitat suitability in Vermont. The atlas of processed geospatial data and workflow outline used to develop this model attached in Appendix 1 will likewise serve Northeast Wilderness Trust and their future partners in executing this pilot study and continuing to develop and adapt this model to suit other locations or target species in the future.

Study Site	***HSI Score***
Trail Around Middlebury (TAM) *(1)*	0.14
Green Mountain Trails *(2)*	0.26
Catamount Family Outdoors Center *(3)*	0.17
Hinesburg Town Forest *(4)*	0.26
Carse Hill *(5)*	0.36

Table 1. Final habitat suitability index (HSI) scores for each of the five identified potential multi-use trail network study sites.

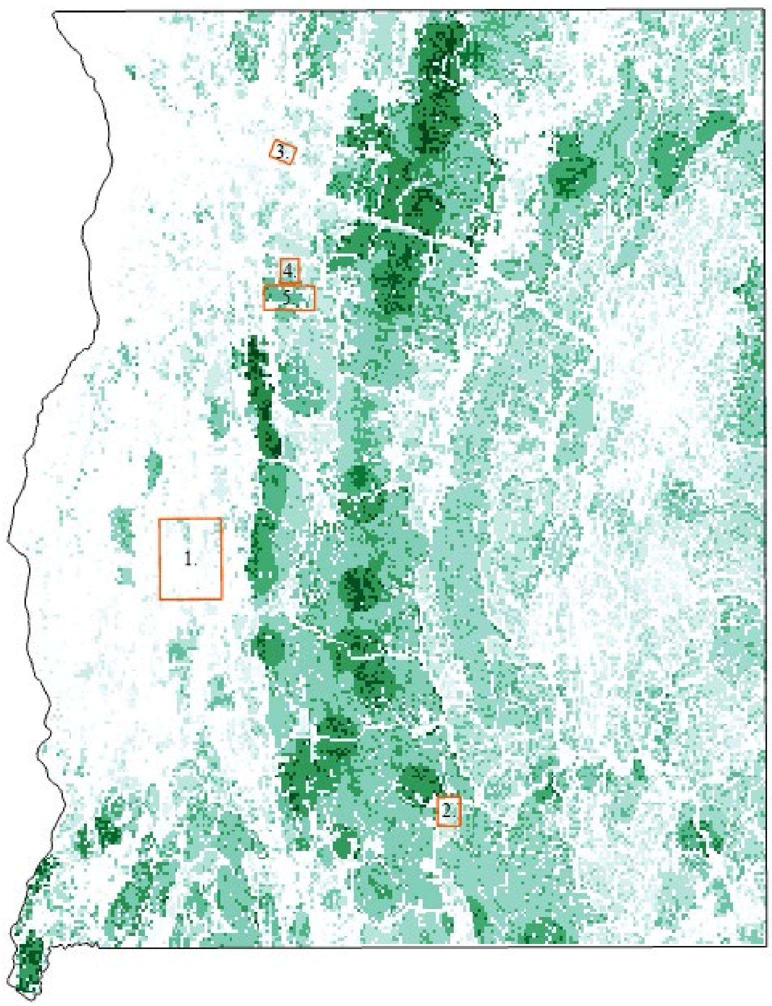

Figure 3. Final habitat suitability index for study region. Dark green indicates high relative suitability, light green indicates low relative suitability, and white indicates unsuitability. Five identified potential multi-use trail network sites outlined in red. 1 corresponds to the TAM, 2 to Green Mountain Trails, 3 to Catamount Family Outdoors Center, 4 to Hinesburg Town Forest, and 5 to Carse Hill.

Conclusion

Based on our research, we feel that recreation in protected areas generally detracts from the goal of preserving areas where wildlife can thrive. While the impacts of recreation vary based on species, location, and type of recreation, there is consensus that human intrusion into protected areas has a negative impact on local wildlife. Animals divert attention from foraging, mating, or raising young to avoid contact with humans. The vast impacts of recreation on wildlife present an uncomfortable conundrum. Human presence in protected areas likely harms the very animals that the protected area is trying to protect. For this reason, we feel that it is crucial for protected areas to have swaths of land set aside where recreation is strictly limited or prohibited. These will be areas where wildlife can survive and thrive without having to expend energy avoiding humans. However, we also feel that, where recreation is necessary to ensure the protection of a piece of land, protection with recreation is far better than no protection at all.

To justify closing off lands to recreation, it is important to conduct studies that are specific to the ecosystem of focus to better understand how recreation impacts local wildlife. In New England, we propose that a study focused on bobcats will serve as a good starting point for addressing the impacts of recreation. It is important to note that such a study would only reveal a small piece of the puzzle. To understand how recreation impacts wildlife at the landscape level, it is important to conduct long-term studies on species at all trophic levels. However, we feel that even a small study on bobcats could provide data that would inform future land management decisions for NEWT.

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Appendix 1: Habitat Suitability Model Procedure

Model Set Up

1. Connect to “Atlas.gdb” in a new ArcGIS Pro project
   - Contents:
     - e911_Address Points
     - VT_Road_Centerline
     - Habitat_Blocks_and_Wildlife_Corridors
     - Hydrography_StreamsRivers
     - Land_Shrublands
     - Land_TreeCanopy
     - NED_Landforms_Vermont
   - *(Data gathered from Vermont Open Geodata Portal and Google Earth Engine)*
2. Delineate study sites
   a. Draw or ingest “StudySites” as polygons
   b. Partition off a “StudyRegion” that includes all “StudySites” and potential control sites to expedite processing time
3. ***Clip*** (feature class) or ***Extract by Mask*** (raster) Atlas contents by “StudyRegion”
   - e911_Address Points → e911_Address Points_StudyRegion
   - VT_Road_Centerline → VT_Road_Centerline_StudyRegion
   - Habitat_Blocks_and_Wildlife_Corridors → HabitatBlocks_StudyRegion
   - Hydrography_StreamsRivers → StreamsRivers_StudyRegion
   - Land_Shrublands → Shrublands_StudyRegion
   - Land_Tree Canopy → TreeCanopy_StudyRegion
   - NED_Landforms_Vermont → Landforms_StudyRegion

I. Cover Suitability Index (CSI)

Development

1. Create buffer around residences or address points of interest
   - ***Select by Attribute*** e911_Address Points_StudyRegion
     - ‘SITETYPE’ = ‘SINGLE FAMILY DWELLING,’ ‘MULTIFAMILY DWELLING,’ ‘CONDOMINIUM,’ ‘MOBILE HOME,’ ‘RESIDENTIAL FARM’
     - ***Buffer*** (Distance = 100 meters) → Residential_Buffer
2. Create buffer around roads
   - ***Select by Attribute*** VT_Road_Centerline_StudyRegion
     - ‘SURFACETYP’ = ‘Paved’
     - ***Buffer*** (Distance = 100 meters) → Paved_Buffer
   - ***Reverse selection***
     - ***Buffer*** (Distance = 50 meters) → Unpaved_Buffer

3. Combine buffers
   Residential_Buffer, Paved_Buffer, Unpaved_Buffer
      Union → Development_Buffer

Landcover

1. Merge shrubland and forest
   Shrublands_StudyRegion and ForestCanopy_StudyRegion
      Merge (Preserve 'Class_name') → ForestShrubland
2. Rasterize land cover characteristics
   Feature to Raster (Field = 'Class_name;' cell size = 30)
      ForestShrubland → ForestShrubland_Raster
      DevelopmentBuffer → DevelopmentBuffer_Raster
3. Manipulate land cover rasters to create model surface
   ForestShrubland_Raster
      Reclassify → ForestShrubland_Reclass
         Shrubland → 1
         Deciduous → 2
         Coniferous → 3
         NoData → NoData
   DevelopmentBuffer_Raster
      Reclassify → DevelopmentBuffer_Reclass
         NoData → 1
         All values within buffer → 0
   Raster Calculator
      ForestShrubland_Reclass * DevelopmenteBuffer_Reclass → Landcover

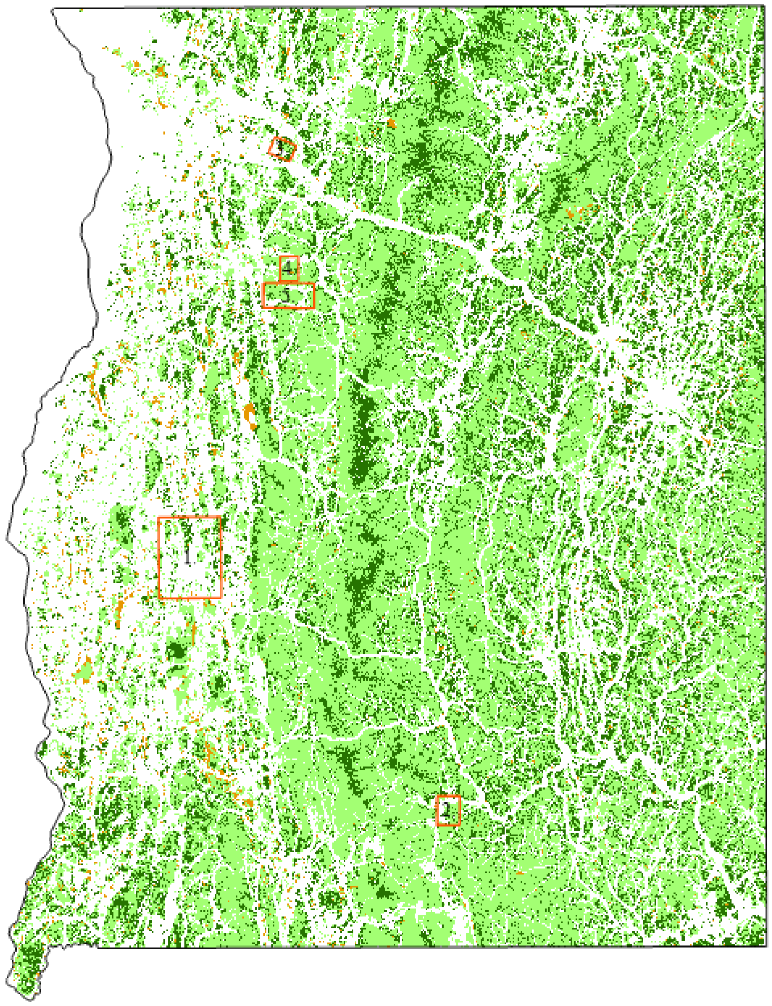

Figure 4. Cover suitability index for study region. Dark green represents coniferous forests, light green deciduous forests, and orange shrublands. Site 1 corresponds to the TAM, 2 to Green Mountain Trails, 3 to Catamount Family Outdoors Center, 4 to Hinesburg Town Forest, and 5 to Carse Hill.

II. Den Suitability Index (DSI)

1. Isolate and generate distance from cliffs

    Create attribute table by generating unique symbology

    Select by Attribute Landforms_StudyRegion

        'VALUE' = 15

        Euclidean Distance → Cliffs_EucDis

2. Specify cliff buffer extent

    Cliffs_EucDis

        Reclassify → Cliffs_Buffer

            0 - 113 → 1

113 - 999999 → NoData

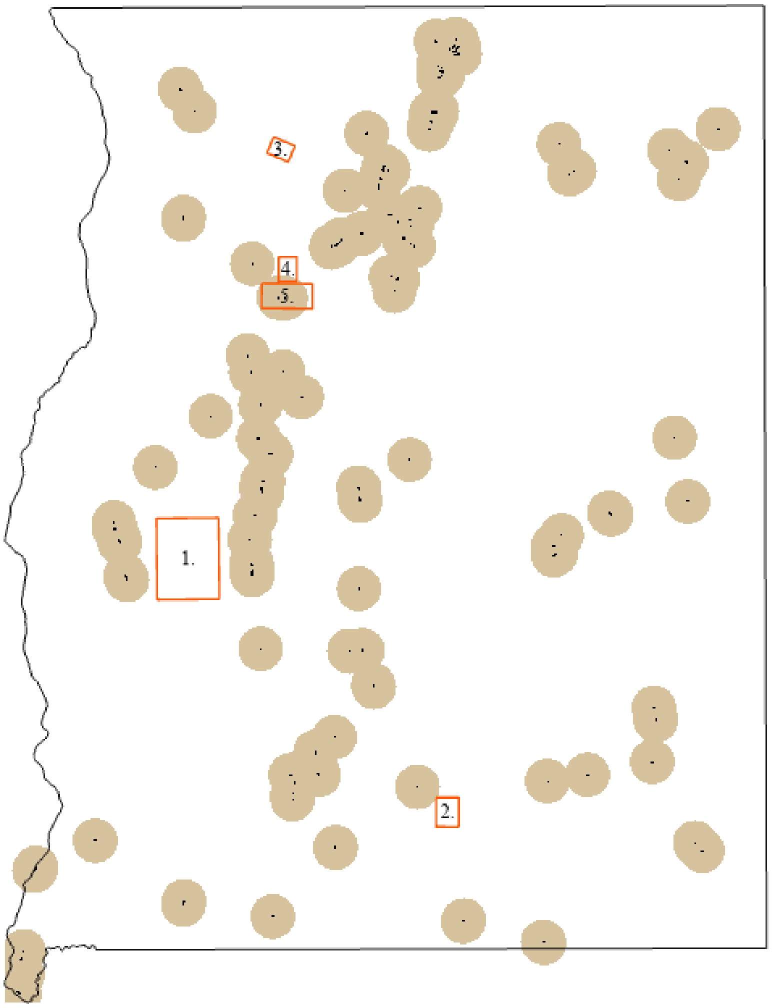

Figure 5. Den suitability index for study region. Areas within 2 hectare area of cliffs represented in beige. Site 1 corresponds to the TAM, 2 to Green Mountain Trails, 3 to Catamount Family Outdoors Center, 4 to Hinesburg Town Forest, and 5 to Carse Hill.

III. Water Availability Index (WAI)

1. Create buffer around streams and rivers

    StreamsRivers_StudyRegion

    Buffer (Distance = 150 meters) → StreamsRivers_Buffer

2. Rasterize water buffer

    StreamsRiver_Buffer

    Feature to Raster (cell size = 30) → StreamsRiver_RasterBuffer

3. Specify water buffer extent

    StreamsRiver_RasterBuffer

    Reclassify → StreamsRiver_Reclass

1 → 1

-1 → 1

NoData → 0

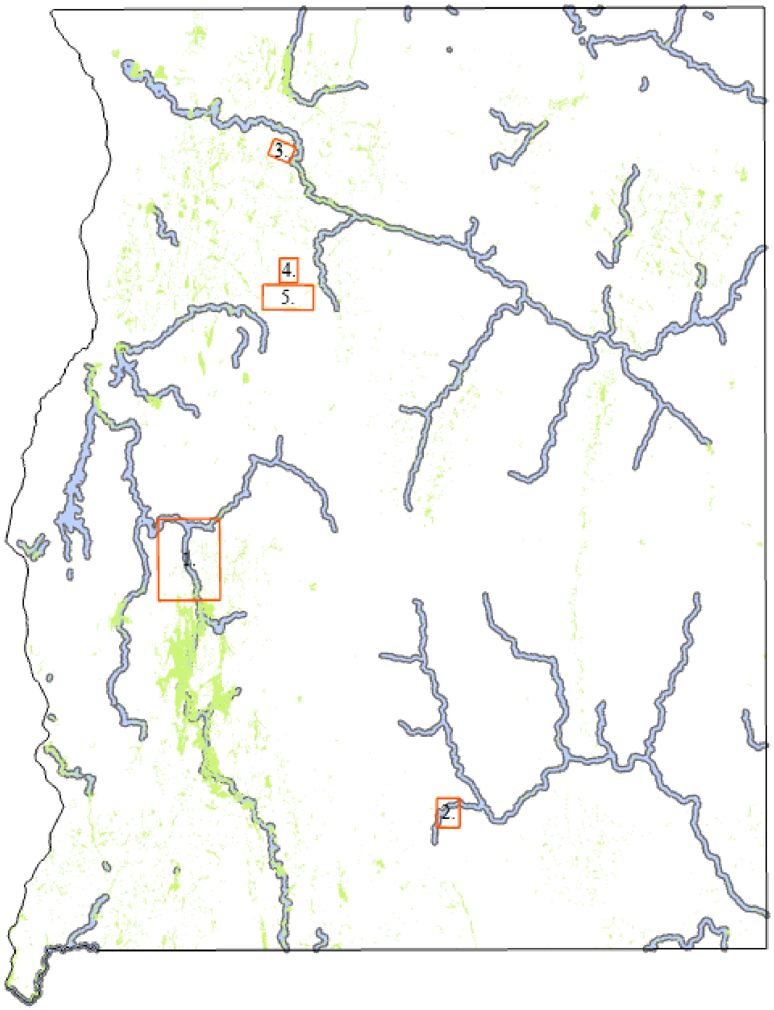

Figure 6. Water availability index for study region. Wetlands represented in green and areas within 150 meters of streams and rivers represented in blue. Site 1 corresponds to the TAM, 2 to Green Mountain Trails, 3 to Catamount Family Outdoors Center, 4 to Hinesburg Town Forest, and 5 to Carse Hill.

IV. Forest Block Index (FBI)

1. Rasterize and rescale forest blocks

HabitatBlocks_StudyRegion

Raster Calculator

(HabitatBlocks_Raster*1.205)/10 → HabitatBlocks_Rescaled

Feature to Raster (Field = 'Fwght;' Cell size = 30) → HabitatBlocks_Raster

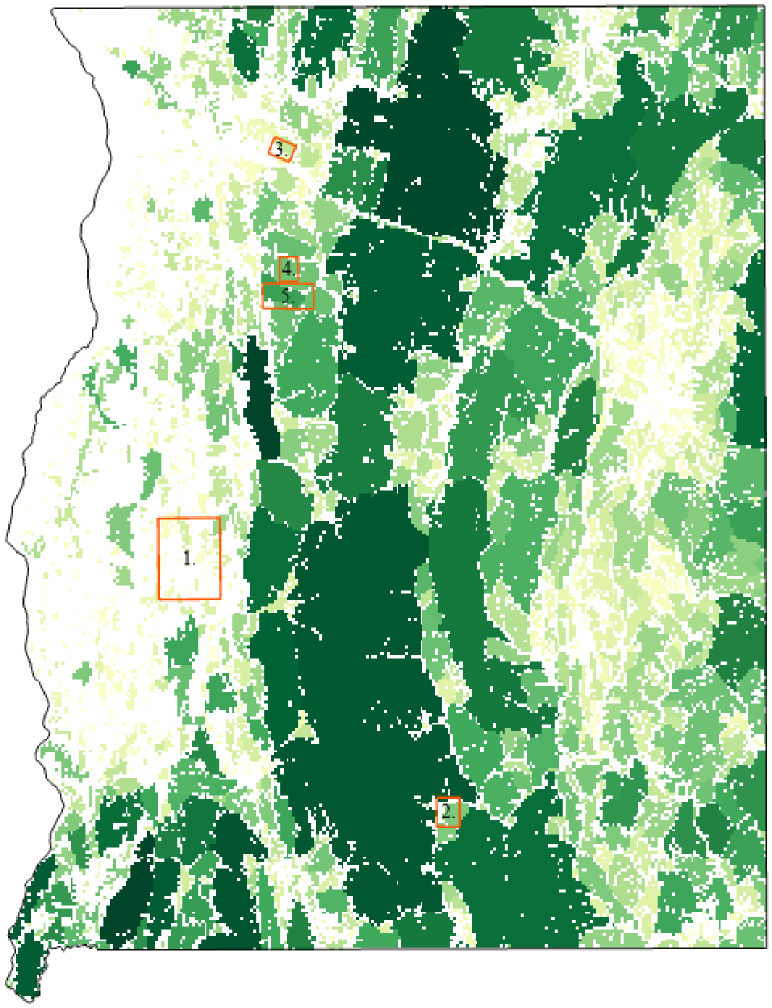

Figure 7. Forest block index for study region. Dark green represents high final weighted score, light green represents low final weighted score, white represents lands that do not qualify in this index. Site 1 corresponds to the TAM, 2 to Green Mountain Trails, 3 to Catamount Family Outdoors Center, 4 to Hinesburg Town Forest, and 5 to Carse Hill.

V. Habitat Suitability Index (HSI)

1. Compute final HSI for study sites

Raster Calculator

HabitatBlocks_Raster*[(Cliffs_Buffer+StreamsRiver_Reclass +Landcover)/5] → HabitatSuitabilityIndex

Zonal Statistics (Input = StudySites; Statistics type = Mean) → StudySite_Suitability